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SIMPLE X-RAY DETECTION INSTRUMENTS FOR TELEVISION SERVICE TECHNICIANS

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
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BRH/DEP 70-14

SIMPLE X-RAY DETECTION INSTRUMENTS FOR TELEVISION SERVICE TECHNICIANS

Richard K. Stoms and Edward Kuerze

Radiation Measurements and Calibration Branch
Division of Electronic Products

June 1970

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
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FOREWORD

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Within the Bureau, the Division of Electronic Products (1) develops and administers performance standards for radiation emissions from electronic products, (2) studies and evaluates emissions of and conditions of exposure to electronic product radiation and intense magnetic fields, (3) conducts or supports research, training, development, and inspections to control and minimize such hazards, and (4) tests and evaluates the effectiveness of procedures and techniques for minimizing such exposures.

The Bureau publishes its findings in Radiological Health Data and Reports (a monthly publication), Public Health Service numbered reports, appropriate scientific journals, and technical report series for the Bureau's divisions, offices, and laboratories.

The technical reports of the Division of Electronic Products (DEP) allow comprehensive and rapid publishing of the results of intramural and contractor projects. The reports are distributed to State and local radiological Health program personnel, Bureau technical staff, Bureau advisory committee members, university radiation safety officers, libraries and information services, industry, hospitals, laboratories, schools, the press, and other interested individuals. These reports are also included in the collections of the Library of Congress and the Clearinghouse for Federal Scientific and Technical Information.

I encourage the readers of these reports to inform the Bureau of any omissions or errors. Your additional comments or requests for further information are also solicited.

John C. Villforth
Director
Bureau of Radiological Health

PREFACE

The development of instrumentation for measuring radiation exposure from electronic products is a major responsibility of the Division of Electronic Products, Bureau of Radiological Health. When adequate or suitable instruments for a particular application are not available, it is the responsibility of the Division's Radiation Measurements and Calibration Branch to develop them. This report describes the results of an effort to design simple and inexpensive instruments that could be used by service technicians to detect x-ray emission from television receivers.

The devices described in this report were designed to be constructed by television and electronic technicians without specialized radiation measurement instrumentation experience. The circuits can be built from commonly available, low-cost components. The use of one of these detection devices will enable a service technician to determine whether a television receiver emits excessive x radiation and, hence, whether repair or adjustment is necessary.

The construction and use of these detection devices by service technicians will provide a partial solution to the problem of detecting excessive x-ray emission from television receivers which are now in the hands of consumers.

Robert L. Elder, Sc.D.
Acting Director
Division of Electronic Products

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ABSTRACT

Simple circuits for detecting x rays by means of a thin (36 mg/cm^2) aluminum-wall organic-quenched cylindrical Geiger-Mueller counter are described. The first presents visible and audio output representing the detector counting rate. The second incorporates a count-rate meter circuit. A manually switched and an electronic oscillator high-voltage supply are described. A simple circuit and procedure for count-rate calibration of the metered circuit are given. All circuits are readily constructed from commonly available components.

SIMPLE X-RAY DETECTION INSTRUMENTS FOR TELEVISION SERVICE TECHNICIANS

INTRODUCTION

Because of the relatively high cost of instrumentation and the skills and radioactive sources needed to ensure calibration, the measurement of x rays emitted from home color television receivers has been restricted primarily to health agencies and television manufacturers. Television service personnel have not become involved in the problem other than to be advised to replace shunt regulator tubes with approved types, adjust high voltage to manufacturers' specifications, and ensure that all covers in the high-voltage section are properly installed. The question does arise as to whether the service industry should become more involved in making measurements of x-ray emission and taking any indicated corrective action. Measurements could be made on both sets housed in cabinets and chassis on service benches.

An instrument would be adequate if it were designed to indicate only whether x rays are emitted at a rate that approaches the 0.5 mR/hr rate specified as a limit by Federal regulation. The instrument need not be calibrated with a high degree of accuracy and, additionally, need not require a meter readout. Availability of such an instrument would enable service personnel to identify radiating sets and provide assurance that corrective action had reduced the radiation well below the specified 0.5 mR/hr.

This report describes two instruments. The first is a low-cost instrument capable of indicating whether a television receiver is emitting sufficient x rays to warrant corrective action. This instrument is easily assembled with low-cost components, many of which are found in the ubiquitous "junk box". The instrument requires no calibration, and the readout is clear and unambiguous.

The second instrument is considerably more complex and designed for those who wish to construct a high-quality Geiger-Mueller instrument for which checkout and calibration in terms of counts per minute require only commonly available service shop instrumentation.

DISCUSSION

There are several methods one might choose to measure x rays emanating from television receivers. One of the best from the standpoint of sensitivity and economy uses a Geiger-Mueller (G-M) tube as the sensing device.

The G-M tube instrument may be broken down into three basic sections: the sensor, high-voltage supply, and readout. G-M tubes consist of a cathode, anode, and filling gas. The filling gas is usually a mixture of a noble gas and a quenching gas such as alcohol vapor or one of the halogens. If a positive voltage is applied to the anode, the electric field is highest around the thin-wire anode and decreases rapidly as the distance from the wire increases. This high electric field gradient around the wire permits operation in the Geiger region, as described below, with a lower applied voltage than would be the case with a thick-wire anode.

Quanta of ionizing radiation, such as x rays and cosmic rays, enter the tube, and a small percentage reacts with either the tube wall or the filling gas to produce free electrons in the gas. As the voltage on the anode is raised from the cathode voltage, some of the free electrons will be collected on the positive anode and some will recombine with gas molecules. As the anode voltage is increased further, more electrons will be collected and less will recombine. If the voltage is raised even higher, a point is reached where the electrons are accelerated to a high enough velocity to knock electrons (secondary electrons) from the gas molecules with which they collide. Thus, more electrons are collected than were originally produced by the radiation. At an even higher voltage, the electrons reach such high velocities that they cause very many secondary electrons, which are in turn accelerated to high enough velocities to produce even more electrons. Thus, an avalanche of electrons is formed and the tube is said to be operating in the Geiger region. In this case, the final number of electrons collected is approximately a constant and independent of the number and energy of the original electrons produced by the radiation. It depends only on the applied voltage within the Geiger region.

The quenching gas operates in such a way as to cause the tube to revert to its previously deionized state after the avalanche occurs. At a sufficiently higher voltage, the G-M tube will go into a state of continuous discharge which generally produces permanent damage. An additional and more detailed description of G-M tubes is given in the bibliography.

DESCRIPTION OF CIRCUITS

Circuits for instruments useful to television technicians for indicating x-ray emission from television receivers have been designed with low cost and ease of construction as criteria. The Geiger tube chosen for the instruments to be described is the Victoreen 1B85 (available from many parts houses). The choice of the 1B85 is based upon its thin wall (36 mg/cm^2, aluminum) which permits measurements of low-energy x rays. The projected area is quite close to the 10 cm^2 over which Federal regulations specify that the x-ray exposure rate from television receivers be integrated.

The high voltage supply for the 1B85 should provide between 800 volts and 1000 volts dc. This is the voltage range over which the tube will operate in the Geiger region. The current required from the high-voltage source is quite minimal. A 0.047-microfarad capacitor charged to 900 volts is sufficient to operate the G-M tube for over an hour at normal background count rates. The high voltage supplies for the survey meters described need not be highly regulated since the variation in counting rate expected from the lowest to highest voltage over which the tube will operate is only about 5 or 6 percent. However, some form of regulation is provided, not so much to ensure accuracy in count rate, but to protect against a catastrophic overvoltage.

The transformers and other components for these power supplies are rather common in "junk boxes". A large number of filament, output, or interstage transformers will work. Regulation is provided by a series of low-cost NE2 neon lamps. Readout of the number of pulses per unit time, which is related to the x-ray exposure rate, may take many forms. The exact form and design of the readout affect the accuracy. For personnel or shops not equipped with radiation standards or the specialized skills necessary to properly calibrate radiation instruments, high precision and accuracy are not attainable. That is not to say that the use of an uncalibrated G-M instrument is meaningless.

Any of the instruments to be described will determine whether a television receiver is emitting x rays and indicate in a general way the source of the x rays (i.e., picture tube or high-voltage component). In all known cases of x radiation the emissions could be reduced to

near zero by high-voltage adjustments (to manufacturers' specifications), replacement of either the shunt regulator or rectifier tubes, or in a few cases, replacement of high-voltage cages or covers which had been left off. These instruments can determine whether or not a television set emits significant radiation and whether or not corrective action has eliminated that radiation.

If the detection of significant x-ray emission rather than an accurate determination of x-ray exposure rate is our goal, then a meter readout is not necessary. Most people are familiar with the popping sound from a set of headphones or small speaker associated with the use of a G-M counter. This type readout is not accurate, but it will certainly indicate large changes in count rate. The average count rate due to normal background radiation will be between about 40 and 150 counts per minute, depending on geographical location, elevation, and possible presence of slightly radioactive materials.

An x-ray field of 0.5 mR/hr produced by a shunt regulator or high-voltage rectifier tube inside a television cabinet will produce a count rate in a 1B85 tube of about 4000 counts per minute. It is therefore obvious whether a television receiver is emitting x rays with an exposure rate significantly above background.

CIRCUIT NO. 1.

A very simple instrument is shown in figure 1. High voltage is developed by repetitively operating switch SW1. The transformer T1 can be selected from a wide range of filament, output, input, and interstage transformers that may be found in "junk boxes". Any of those shown on the parts list is adequate. Several operations of SW1 should suffice to charge capacitor C1 to its terminal voltage. Once capacitor C1 is charged, it will power the 1B85 for about an hour at background rates and over 10 minutes at 4000 counts per minute. This allows ample time to check a television set for radiation emission.

The phasing of the transformer T1 must be such that when SW1 is operated, the increasing current in the primary (low turns side), which occurs each time the wiper makes contact, induces a negative voltage at the high side of the secondary. This forward biases diodes D1 and D2 which clamp the T1 secondary to ground, and no voltage appears across the NE2 lamps. When the wiper moves off of a contact, current is suddenly cut off, producing a high positive voltage at the high side of the secondary. The diodes D1 and D2 are now back biased and the positive voltage is applied to the NE2 lamps. Note that SW1 is any type of rotary switch that has a "break before make" action. Thus, rotating SW1 will alternately close and open the primary circuit of T1.

An 11-position single-deck switch is desirable, although any number of positions will work well. SW1 should never be left in an intermediate position so that T1 primary current flows continuously, as this will rapidly discharge the batteries.

The voltage from an adequate transformer is sufficient to cause conduction in the string of NE2 lamps. Current through the lamps charges C1. When the C1 voltage is below the extinguishing voltage of the NE2 string, C1 will charge with every pulse. However, when C1 is charged to about the extinguishing voltage, the next pulse will charge it above this voltage. In this case, C1 will charge to a higher voltage during the pulse and then discharge back through the NE2 lamps until their extinguishing voltage is reached. Thus, the terminal voltage on C1 will be determined by the extinguishing voltage of the NE2 lamps.

In selecting a transformer, all one has to do is set up the high-voltage circuit as shown. An acceptable transformer will produce noticeable flashes in the NE2 lamps every time the SW2 is rotated. If no flashes occur, either the primary or secondary leads should be reversed. Also to provide some safety margin, 18 NE2 lamps should be used in selecting a transformer. D1 and D2 used by the authors are Sarkes-Tarzian F8 diodes at 800 volts peak inverse. They are avalanche protected which undoubtedly is the reason they work in this circuit. The voltage appearing across the combination is approximately the voltage on C1 (about 900 volts) plus the voltage required to ignite the NE2 string (about 1100 volts). This adds up to about 2000 volts. To allow for some safety margin, nonavalanche-protected devices should be rated at about 3 kV peak inverse. Stacking nonavalanche-protected diodes in pulse circuits of this type does not usually prove satisfactory unless bleeder resistors are used. Bleeders in this circuit are not recommended.

As mentioned above, 18 NE2 lamps are used in selecting a transformer. Space should be provided on the circuit board for 18. The exact number to be used in the final circuit will depend on the specific lamps used. The method of selecting the final number is described below.

The high voltage is applied to the 1B85 through the anode load resistor R1. The value of R1 is not critical, and any value between about 1 megohm and 10 megohm can be used. The signal produced by a Geiger discharge at the 1B85 anode is a negative pulse as shown. Its amplitude and width are primarily functions of the high voltage, load resistor, coupling capacitor, and following-stage input impedance. Typically, it is about 2 volts peak and 20 microseconds wide with the values shown. Many service oscilloscopes will not reproduce it.

Q_1 is an amplifier used to increase the signal level and invert the pulse to drive the monostable multivibrator Q2 and Q3. The use of a field effect transistor (FET) in this stage is not mandatory although it performs the required function well with few components and without substantially loading the 1B85 output. A standard bipolar transistor properly biased and with an adequate frequency response will suffice in lieu of an FET.

Q2 and Q3 compose a one-shot or monostable multivibrator. Normally, R7 will cause Q2 to be cut off so that the voltage drop across R5 is zero. This in turn causes Q3 to be cut off. A positive pulse at the base of Q2, derived from the preceding stage (Q1), will start to turn Q2 on. The falling voltage at the collector of Q2 and hence at the base of Q3 will start Q3 to conduct. The increasing voltage at the Q3 collector is coupled to the Q2 base through R8 and C4 which further tends to cause Q2 to conduct. This positive feedback action will cause the collector current of Q3 to increase rapidly and remain until C4 becomes fully charged and positive feedback action ceases. This causes Q2 and Q3 to revert to the nonconducting state. The magnitudes of R7, R8, C4, and collector load of Q3 will determine the output pulse width.

A neon lamp and an earphone are shown in figure 1 for readout. Either or both may be used. The transformer T2 can be selected from a wide variety of types, some of which are shown in the parts list. The earphone is a low-impedance type generally sold with transistor radios, tape players, etc. Most speakers will also work quite well. Figure 2 shows one way to assemble the meter and the method of mounting the G-M tube.

CIRCUIT NO. 2.

For those who prefer not to operate a switch to obtain high voltage, the circuit of figure 3 will prove useful. This is not the most efficient circuit, but it does permit flexibility in the selection of components. The free-running multivibrator, Q1 and Q2, is quite similar to the one-shot multivibrator (MV) shown in figure 1. In fact, the only difference is that R7 in figure 1 is deleted and replaced by R1 in figure 3. R1 is selected so that Q1 conducts slightly. This slight conduction sends a signal through Q1 collector to Q2 base and hence through Q2 collector back to Q1 base. This positive feedback action turns Q2 on hard until C1 is fully charged and positive feedback action stops, at which time Q1 and Q2 turn off and the cycle is repeated. The on and off times of this circuit are not necessarily equal. With a fixed C1, the on time is determined primarily by R4 and the repetition rate by R1. The transformer is more critical than

the one in figure 1 because Q2 cannot interrupt current as quickly as a mechanical switch nor can it supply as much current to the transformer as the switch.

The Triad A-1X transformer is effective in this circuit and is reasonably priced. Other transformers have worked but at the expense of a much higher battery drain, marginal voltage output, or considerably higher price. Note that the secondary operates into a standard halfwave rectifier circuit. D1 and D2 are Sarkes-Tarzian F8 diodes. The peak inverse voltage (PIV) in this case is limited by the breakdown voltage of the NE2 string (about 1200 volts). Earlier comments in regard to diode stacking also apply here, although the diodes now will have only about a 1200 PIV rating.

All the circuits including the one in figure 4 should be enclosed in and grounded to a metal box since they are sensitive to electromagnetic fields, especially that caused by the horizontal output circuit in a television receiver. A rectangular hole is cut in the side so that the G-M tube is exposed. The hole should be 2-3/4 by 3/4 inch. If any RF sensitivity is evident, the hole may be covered with one layer of aluminum foil glued in place. It is recommended the high-voltage section be located as far from the input circuitry as possible.

The G-M tube poses some problems. "As received" it will have a black coating over the glass seal on the anode end. This coating can become scratched, allowing light to enter the tube. Light, especially sunlight, can cause ionization and hence the tube will count as though irradiated by x rays. If the tube counts in the light but not in the dark, the paint should be removed with acetone or a paint remover and thoroughly cleaned with either acetone or high-purity alcohol. When dry, the glass seal should be recovered with a black silicone rubber such as GE RTV-103.

The tube may be mounted in a 3/4-inch fuse clip which is grounded. The anode connection may be made with any type of grid connector that will fit a 1/4-inch-diameter connector, or several turns cut from a spring can be pushed over the anode connector. Connection should not be made by soldering to any part of the tube.

The thin wall and low internal pressure make the tube susceptible to crushing and denting. No attempt should be made to remove dents, since a tube may work satisfactorily if the central wire is not disturbed or the tube did not suffer an air leak. If the dent damaged the tube, it cannot be repaired. The tube should be handled only at the anode end, especially when inserting in the mounting clip.

As previously mentioned, provision should be made on the circuit

board for 18 NE2 lamps. The high-voltage circuit should work with all 18 lamps in series. The G-M tube should not be connected to the high voltage until the entire circuit is finished. At this time, 5 of the NE2 lamps should be shorted out with a jumper so that 13 are in series (applies to either version of the high-voltage circuit), the G-M tube should be inserted, and the circuit turned on (operate SW1 in figure 1 circuit). The high voltage should be too low, and there will be no output indicated on either the NE2 or earphone. The circuit should then be turned off, the jumper reconnected to place 14 NE2 lamps in series, and the circuit turned on. This should be repeated, increasing the number of neons by one each time until an output indication is obtained from background radiation. It will be necessary to wait up to 15 seconds to determine if the tube is counting since the background count rate is low and random. One more NE2 should be added in series after counting starts.

A word of caution, the high-voltage capacitor should not be shorted when it is charged and transistor Q1 (figures 1 and 4) is in the circuit. The resulting sudden change in voltage can damage the gate of Q1. The transistor should either be removed if sockets are used or a lead should be connected from the gate to ground when working on the high-voltage circuit. An alternate method to bleed down the high voltage is to short it to ground through a 10-megohm resistor. This can be done with Q1 in the circuit.

CIRCUIT NO. 3.

The circuits described above are adequate for the purpose of detecting x rays that may emanate from color television receivers. They are not capable of very accurate measurement of the count rate produced by a G-M tube.

The circuit shown in figure 4 is capable of more accurate measurement of G-M tube counting rate. The power supply shown in figure 3 is used to generate the high voltage. The transistor Q1 and monostable multivibrator Q2 and Q3 are as previously described except for a change in the collector circuit of Q3.

The accuracy of this count-rate meter depends on maintaining a fixed output pulse width with decreasing battery voltage. The zener diode D1 ensures a fixed pulse width under this condition.

The monostable output pulse is applied through D2 to an integrating circuit composed of Q4, R11, R12, R13, and C4. Q4 is a constant-current generator whose output is independent of the supply voltage, in this case the amplitude of the monostable output pulse.

The current through Q4 is adjusted to approximately 0.8 mA by selecting R11. A 6-volt battery is connected to the cathode of D2 with the minus side of the battery grounded (no other voltages in circuit). R11 is selected so that a 0-1 mA meter connected across R12 and R13 reads about 0.8 mA. Changing the 6-volt battery to 12 volts should not change the 0.8 mA reading. Because of this and the zener diode D1, the supply voltage need not be regulated.

The input to the integrating network could be taken from the top of D1 rather than R9, but this would not provide any better regulation and would provide a lower voltage to the integrating circuit, limiting its range.

In operation, C4 is charged by current pulses through Q4. Each pulse from the G-M tube results in a constant-amplitude (due to constant current Q5) and constant-width (ensured by D1) current pulse into C4. In other words, a constant amount of charge is delivered to C4 for each pulse. Constant current will flow into C4 with a voltage on C4 of the order of 6 or 8 volts. If, as is often done, C4 is charged through a resistor rather than a constant-current generator, the change in voltage on C4 is substantially different for various C4 voltages. R13 is provided to adjust the voltage output.

The C4, R12, R13 network cannot be loaded by a succeeding stage if proper operation is to be maintained. A high-impedance voltmeter is required to read the voltage on this network. A standard 10-megohm-input vacuum tube voltmeter (VTVM) is satisfactory but not very portable. Commercial FET voltmeters should prove adequate, and most are portable.

If such a meter is not available, the measurement can be made with the circuit shown connected to this network. Q5 through Q9 constitute an FET voltmeter. This circuit has several advantages. The input impedance is high, linearity up to about 8 volts (with a 12-volt supply) is excellent, and about any meter with 1-mA full-scale sensitivity or better may be used. A 10-mA movement could probably be used if R14 and R15 were to be reduced to 100 ohms. This is in contrast to most FET voltmeter circuits that require a 50-or 100-μA movement.

Q9 and R16 constitute a constant current generator. R16 is selected to produce a constant voltage drop of one volt across R20, which is used to set zero. R21 is shunted across R20 after the circuits have been completed and are operational. R21 is selected so that adjustment of R20 moves the pointer of the meter about plus or minus 20 percent when the selector switch is on "zero" position. In operation, a voltage will appear across R14 and R15 which is dependent on the characteristics of the specific transistors used. A voltmeter connected from R14 to R15, with the gates of both Q5 and Q8 grounded (or at zero

voltage), will show that one voltage is higher. If the voltage on R15 is higher, the transistors should be interchanged so that R14 voltage is higher. This is done so that the zero adjustment R20 can bring the R15 voltage up to zero the meter.

When the voltage on the gate of Q5 is increased, the voltage on R14 also increases. The voltage on R15 remains fixed so that the difference in voltage between R14 and R15 is a measure of the gate voltage of Q5. If the gate voltage of Q8 were to increase with that of Q5, the difference across R14 and R15 would be zero. The time-constant capacitor C5 couples fast changes in voltage to the gate of Q8 so that the meter reading for fast changes is zero, allowing only slow changes to cause a meter reading. Three ranges of "slowness" may be obtained with the time-constant switch SW1.

The selection of meter ranges will depend on the use of the instrument and on the selection of a meter movement. If, for example, ranges (full scale) of 1000, 3000, 10,000, 30,000, and 100,000 counts per minute are desired, the total range is 100 to 1. If a 50-millivolt meter movement is available, the upper voltage to be delivered by the integrating circuit and voltmeter circuit is 5 volts, which is well within their capabilities. A 100-millivolt movement would require a 10-volt upper range which could be obtained by an 18-volt supply voltage to the monostable multivibrator, integrating circuit, and voltmeter circuits. Meters with a higher millivolt requirement would necessitate restricting the ranges or arranging to switch in various values for R12 and R13 (or alternately R11).

The instrument is calibrated (in counts per minute) by disabling the high voltage or by removing the G-M tube. Resistors in the meter circuit, R22 through R26, should be selected to provide full-scale meter readings for the desired set of full-scale input voltages at the Q5 gate (e.g., 0.050, 0.150, 0.50, 1.50, and 5.0 volts full scale for the 1000 to 100,000 count-per-minute ranges mentioned previously). Input voltage can be obtained from a battery and potentiometer applied directly to the Q5 gate without disconnecting previous circuitry.

A pulse generator (negative pulse of about 0.5 to 2.0 volts peak with a rise time on the order of 0.1 microsecond and a width less than 100 microseconds) may be connected to the junction of R2 and R3. The pulse rate can be related to the meter reading by adjustment of R13. Only one point need be adjusted. The circuit in figure 5 is a convenient way to obtain 3600 counts per minute. The clip is connected to the R2-R3 junction. Usually no ground is required. If so, touching the chassis is usually sufficient.

The battery test resistor R27 on the range switch is selected to provide a full-scale meter reading with fresh batteries.

OPERATION OF INSTRUMENTS

Normal background count rates will probably fall between about 40 and 150 counts per minute. Any x-ray emission high enough to justify corrective action will increase this count rate substantially. If there is any question or doubt that the rate has increased, it has not.

In a conventional television receiver, x rays are generated by the picture tube, shunt regulator, and high-voltage rectifier. Thus, a quick pass, say 30 seconds, across the picture tube face will suffice for this area. Some cathode ray tubes (CRT) emit x rays from the funnel. In some cases these will be transmitted through the cabinet. If the tube emits from the face, it will emit over most of the face area.

The regulator tube and rectifier are usually placed on the opposite side of the cabinet from the tuner. Hence, a pass around the rear, top, side, and, if accessible, the bottom of the set in the vicinity of the high-voltage components and CRT should be all that is necessary. Sometimes the x rays exit in a narrow beam so that it is desirable to sweep as great a percentage of the surface in the high-voltage component area as possible. Until familiarity with the measurement is acquired, it is suggested that the instrument be moved across the surface at a rate of about 1 foot in 15 seconds.

SUMMARY AND CONCLUSIONS

A simple Geiger-Mueller tube instrument may be built with inexpensive components, many of which can be found in "junk boxes". The instrument avoids the problem of calibration and interpretation of results by not having a meter display. A neon lamp or earphone, or both, are used to indicate the presence of x rays. An increase in flash rate or sound-pulse rate indicates that a television receiver emits sufficent radiation to warrant corrective action. Any definitely noticeable increase of background count rate may be judged sufficient to require correction to reduce the radiation. The instrument will also locate the area from which radiation is being emitted, thus facilitating location of the radiation source.

For those wishing more detailed information about the x-ray field, a more complex instrument is described. This instrument can be constructed and calibrated in counts per minute using equipment found in all service shops.

Neither instrument is specifically adapted for large-scale production. Instead, the emphasis is placed on an instrument design that facilitates construction by service shops and technicians without specialized equipment.

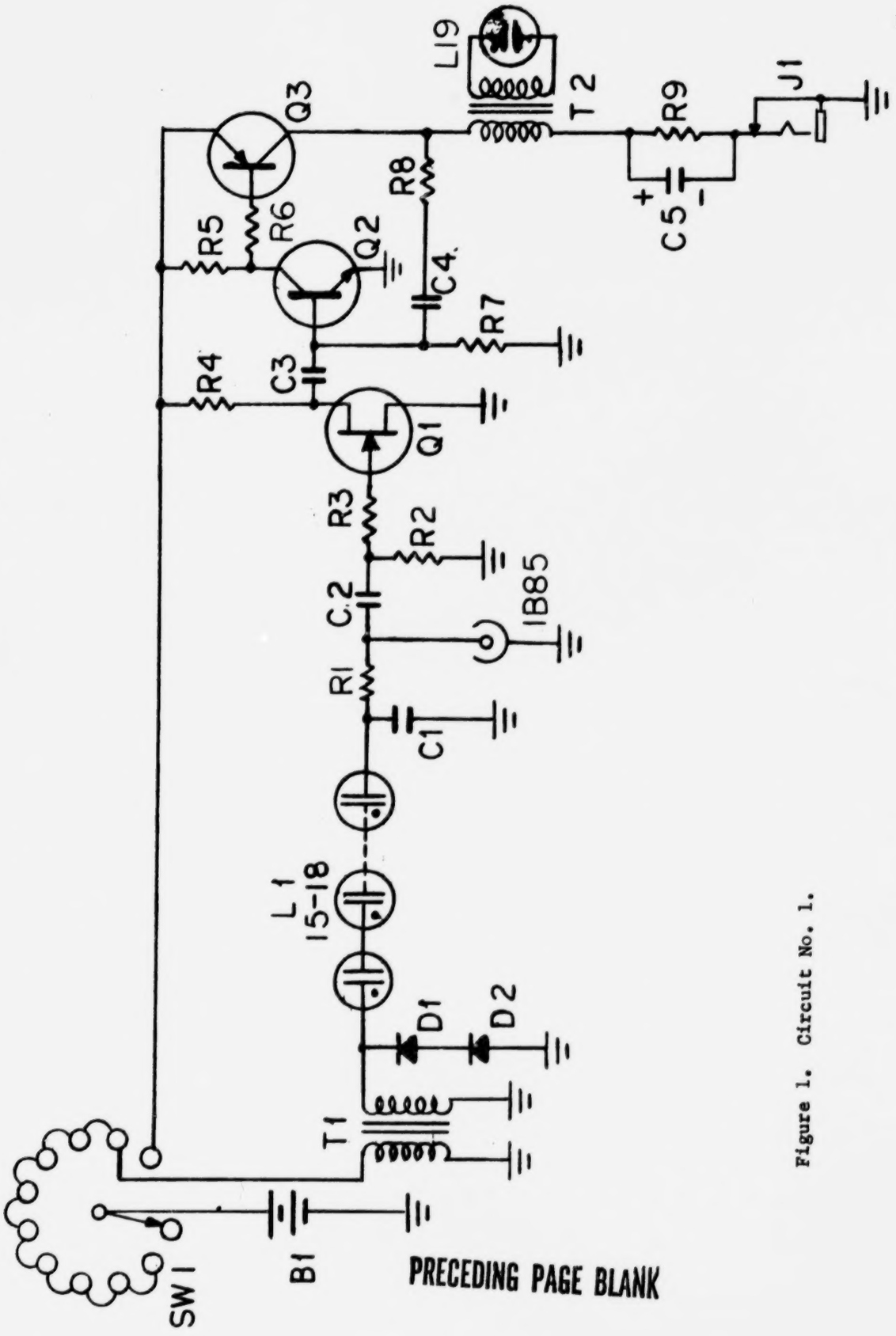

Figure 1. Circuit No. 1.

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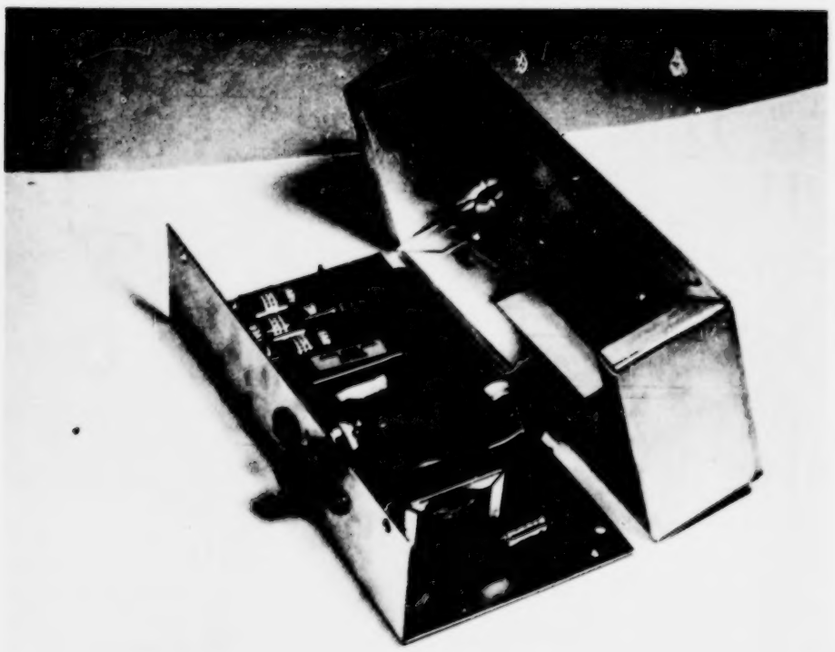

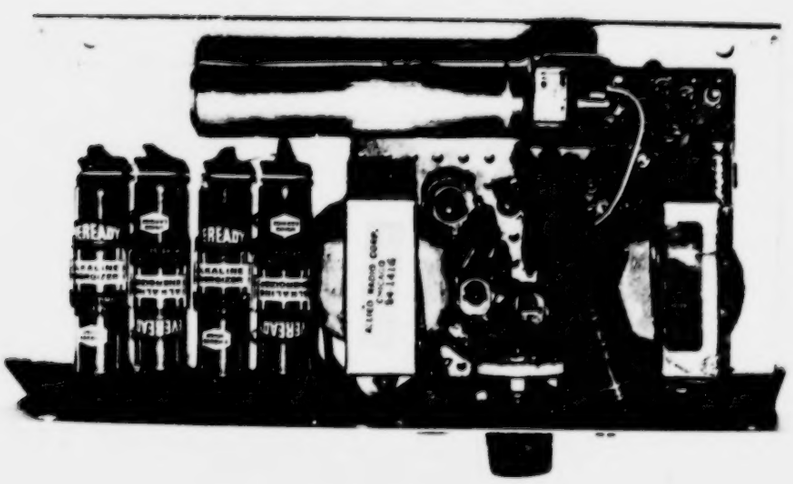

Figure 2. Two views of an instrument built from Circuit No. 1.

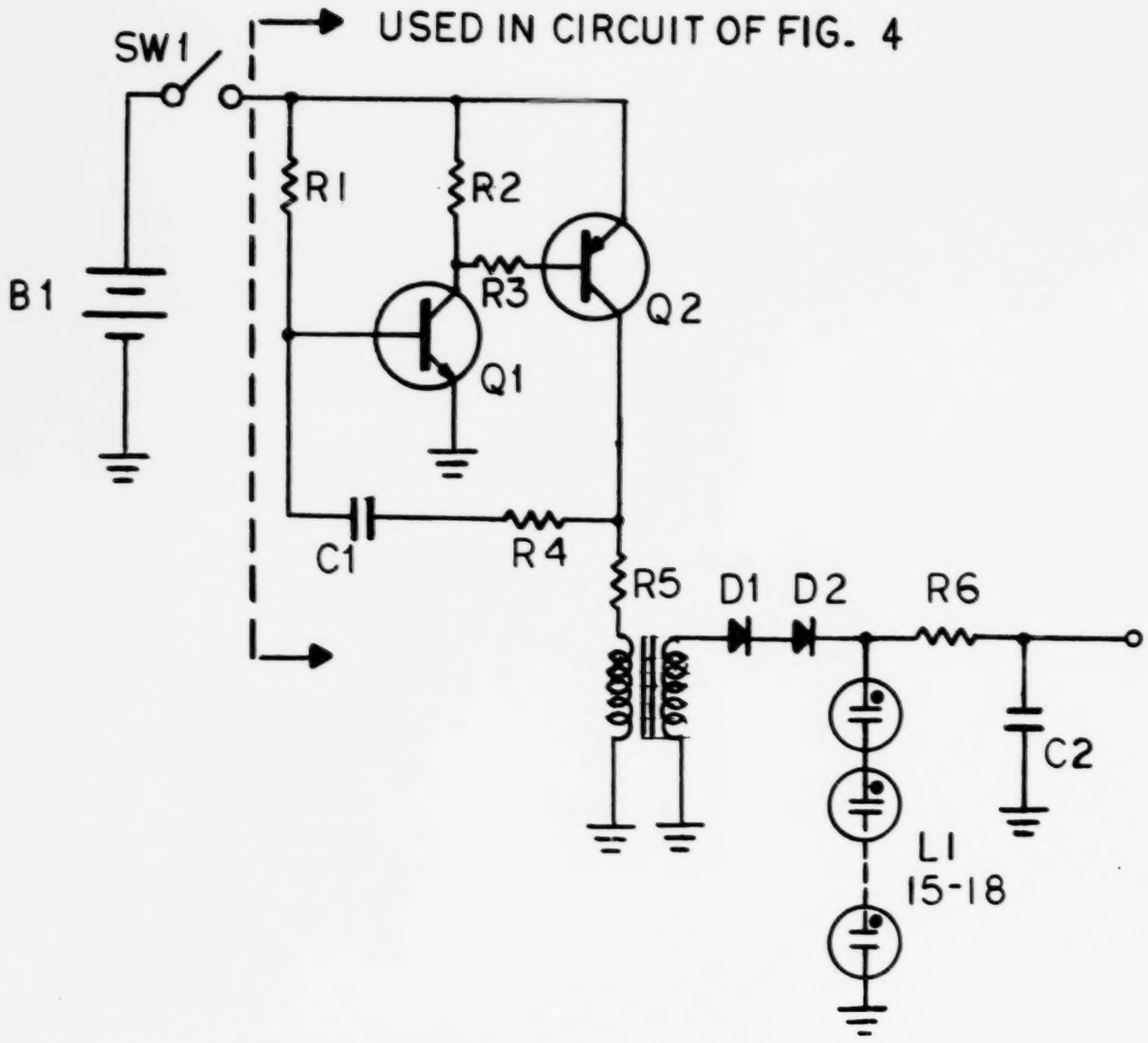

Figure 3. Oscillator high voltage supply.

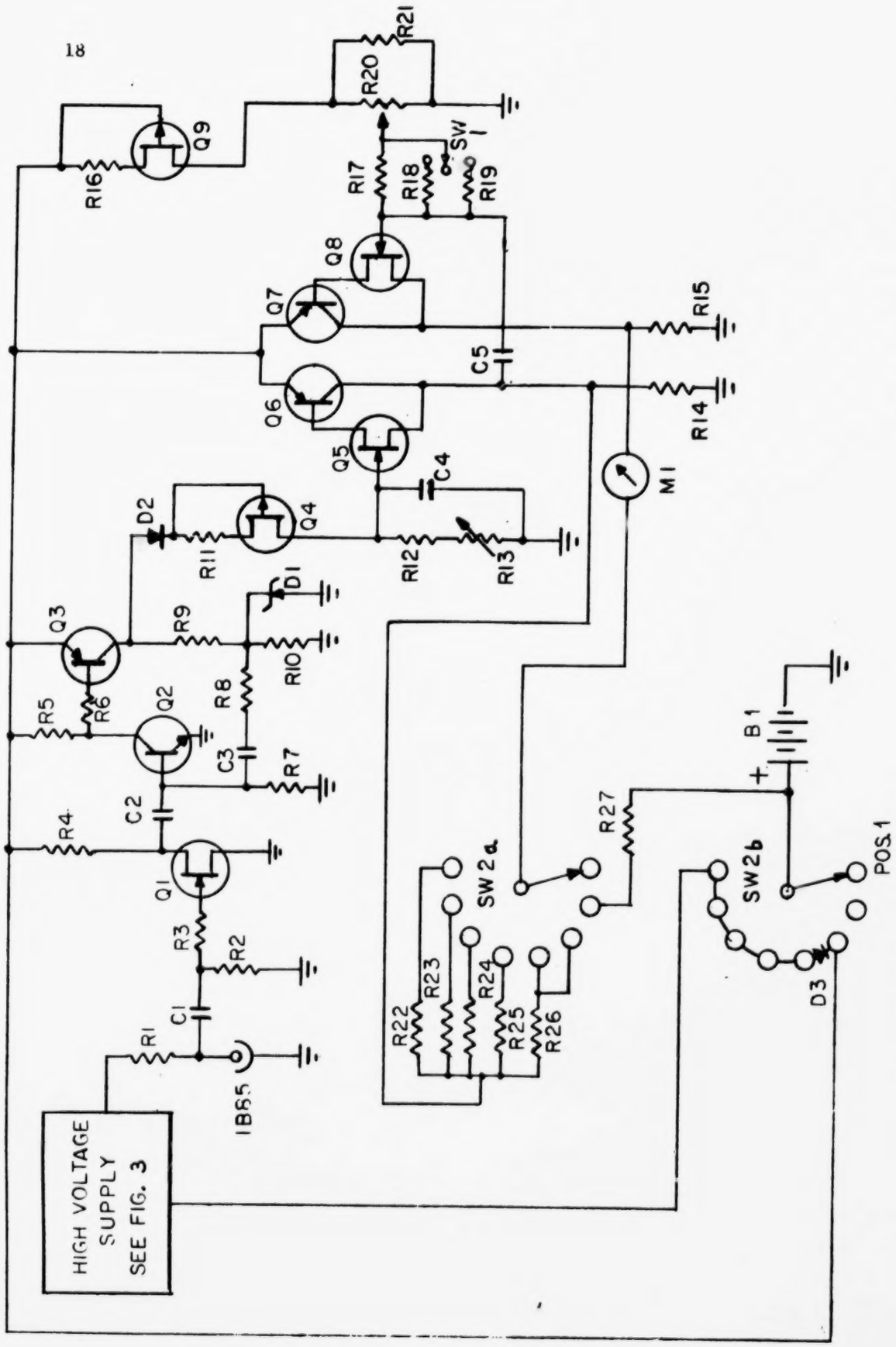

Figure 4. Circuit No. 3.

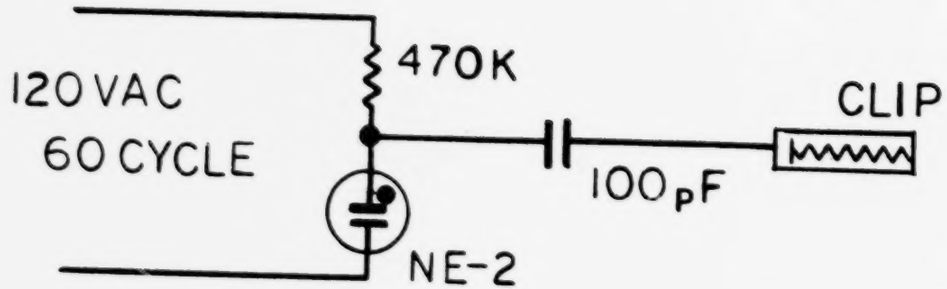

Figure 5. Test pulse generator.

PARTS LIST (For Figure 1)

B-1	-	6 volt (4 AA cells)
R1	-	10 M ohm
R2, R3	-	100 k ohm
R4, R7	-	10 k ohm
R5, R9	-	1 k ohm
R6	-	560 ohm
R8	-	15 k ohm
C1	-	0.047 µfd 1600 V
C2	-	0.001 µfd 2 kV
C3	-	100 pfd
C4	-	0.1 µfd
C5	-	20 µfd 15 V
D1, D2	-	F8 Sarkes-Tarzian
Q1	-	2N5457 (MPF 103), or 2N4221 (Motorola)
Q2	-	2N635A, 2N697, 2N706, 2N1605, 2N3567, 2N3646 or 2N5133
Q3	-	2N404, 2N414, 2N652, 2N741, 2N1038, 2N1193, 2N3133, 2N3638, 2N3645, 2N5140 or MA206
T1	-	6.3 volt filament transformer (Allied 54-1416) or output transformer (Allied 54-1449) or input transformer 100/98500 ohm (Triad A-1X) or many others typical of the above.
T2	-	Same as T1, plus input transformer (Calectro D1-719) or input transformer 10 K/2 k ohm (Lafayette 99-6124).
L1 to L18	-	Ne-2
L19	-	Ne-2 or Ne-51
SW1	-	Any 3-11 position switch, "break before make".

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PARTS LIST (For Figure 3)

R1	-	See text.
R2	-	1 k ohm
R3	-	560 ohm
R4	-	15 k ohm
R5	-	22 ohm
R6	-	100 k ohm
C1	-	0.1 μfd
C2	-	0.047 μfd 1600 V
D1, D2	-	F8 Sarkes-Tarzian
Q1	-	2N3567 > (Fairchild)
Q2	-	2N3638 > (Fairchild)
L1 to L15 or L18	-	Ne-2
Transformer	-	100 ohm/98,500 ohm (Triad A-1X)
Battery	-	12 volt

PARTS LIST (For Figure 4)

R1	-	10 M ohm
R2, R3	-	100 k ohm
R4, R7	-	10 k ohm
R5-R14, R15	-	1 k ohm
R6	-	560 ohm
R8	-	6.8 k ohm
R9	-	100 ohm
R10	-	470 ohm
R12	-	82 k ohm
R13	-	50,000 ohm pot
R17	-	10 M ohm
R18	-	220 k ohm
R19	-	2.2 M ohm
R20	-	1,000 ohm pot
R11, R16, R18, R19, R21 through R27	-	See text
C1	-	0.001 µfd 2000 V
C2	-	100 pfd
C3	-	0.001 µfd
C4	-	0.1 µfd
C5	-	1 µfd paper
D1	-	1N713A
D2	-	1N914B
D3	-	1N99
Q1, Q5, Q8	-	2N5457 (MPF103) (Motorola)
Q2	-	2N5133
Q3	-	2N3638 (Fairchild)
Q4, Q9	-	2N4360
Q6, Q7	-	MPS. A66 (Motorola)
SW1	-	Single pole, double throw, center-off toggle switch
SW2	-	2 pole, 8 position rotary switch

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SIMPLE X-RAY DETECTION INSTRUMENTS FOR TELEVISION SERVICE TECHNICIANS.
U.S. Department of Health, Education, and Welfare, Public Health Service Publication Number BRH/DEP 70-14 (July 1970), 25 pp. (limited distribution).

Accession No.

ABSTRACT: Simple circuits for detecting x rays by means of a thin (36 mg/cm^2) aluminum-wall organic-quenched cylindrical Geiger-Mueller counter are described. The first presents visible and audio output representing the detector counting rate. The second incorporates a count-rate meter circuit. A manually switched and an electronic oscillator high-voltage supply are described.

(over)

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